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TENTATIVE GUIDELINES FOR CONSTRUCTION OF CEMENT CONCRETE PAVEMENTS IN COLD WEATHER

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CONTENTS

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1. GENERAL

1.1. Although India is a tropical country, many parts in the Northern region are subject to extremely low and subfreezing temperatures in the winter season. While it is imperative to carry out concrete construction in such areas during the summer period, it may not always be possible to observe such restrictions, and construction period may have to be extended to the maximum possible limits. In view of the slow rate of setting and strength development of concrete at lower temperatures and susceptibility of concrete to frost damage at subfreezing temperatures, it is essential to observe special precautions in case of such cold weather concreting.

1.2. The methods recommended for adoption in case of cold weather or winter concreting are given in these guidelines. The guidelines are intended to ensure the quality construction of concrete pavements in cold weather, limiting the adverse effects of such weather on concrete pavement construction to the minimum. These guidelines are intended to supplement IRC: 15-1981 "Standard Specifications and Code of Practice for the Construction of Concrete Roads (Second Revision)", and should be used in conjunction therewith.

1.3. The Tentative Guidelines for Construction of Cement Concrete Pavements in Cold Weather were prepared by the Cement Concrete Road Surfacing Committee (personnel given below) and the final draft Guidelines were finalised by the Committee in their meetings held at Bhubaneshwar on the 24th December, 1982 and at Nagpur on the 8th January, 1984.

K. K. Nambiar	....	*Convenor*
Y. R. Phull		*Member-Secretary*
H.S. Bhatia		T. A. E. D'sa

Note: These Guidelines are intended specifically for cement concrete pavements. For cold weather concreting in general, reference may be made to IS: 7861 (Part II)—1981 "Code of Practice for Extreme Weather Conditions" Part II—Recommended Practice for Cold Weather Concreting.

P. V. Kama	A Rep. of National Council for Cement and Building Materials
G. P. Lal	President, Indian Roads Congress (V.S. Rane) -*Ex-officio*
P. J. Mehta	Director General (Road Development) & Addl. Secretary to the Govt. of India (K.K. Sarin) -*Ex-officio*
V. Raghavan	Adviser, Indian Roads Congress (P.C. Bhasin)-*Ex-officio*
A. Sankaran	Secretary, Indian Roads Congress (Ninan Koshi)-*Ex-officio*
N. Sivaguru	
G. Raman	
Maj. Gen. J. M. Rai	
K. B. Rai	
A. S. Bhatnagar	
City Engineer, (Roads) Bombay Municipal Corporation	

Later on, the above mentioned draft guidelines were processed and approved by the Specifications & Standards Committee and the Executive Committee in their meetings held at New Delhi on the 21st August and 22nd August, 1985 respectively for being considered by the Council. The Council in their 114th meeting held at Panaji (Goa) on the 6th September, 1985 approved these Guidelines for being published by the Indian Roads Congress.

2. SCOPE

2.1. Although it may be difficult to pinpoint the lowest temperature below which the cement concrete paving works having large surface areas exposed to cold weather would be adversely affected, a temperature of 4°C may be considered as the critical one for adoption of special precautions, especially in view of expansion of water on cooling below this temperature and possibility of consequent development of disruptive volume changes in fresh concrete.

2.2. These guidelines cover the special measures and precautions required for carrying out concrete paving works at ambient temperatures below 4-5°C, as well as special precautions impereative, in case of concrete pavements subjected to sub-freezing temperatures after construction even when construction is not required to be carried out in cold weather.

3. PROBLEMS ASSOCIATED WITH COLD WEATHER CONCRETING

3.1. Problems associated with cold weather concrete may broadly be considered in two groups: (a) those due to low temperatures above freezing point, and (b) those due to temperature below freezing point.

3.2. As setting and hardening of cement is a hygrothermal phenonmenon, at low tempratures the setting and hardening

reactions of concrete proceed at a slower rate than at the normal temperatures. The setting of concrete, as well as its strength development will, therefore, be much slower at low temperatures, necessitating retention of formwork for longer periods, and extended curing. Whenever the ambient temperatures are considered too low to obtain satisfactory results by such extended measures alone or such extension of curing period is not practicable due to any reasons, additional measures to rise the temperature at which concrete is laid and cured will be required.

3.3. Fresh concrete subjected to subfreezing temperatures can experience substantial loss of strength and damage to concrete. Frost damage to concrete is independent of the freezing temperature and mix proportions of concrete. The decrease in strength may be 30-40 per cent for concrete frozen immediately after placement. If freezing occurs after 24 hours of placement, the loss is somewhat less. However, concrete once damaged in this manner will not recover the strength equivalent to that of unfrozen concrete, and it is important to take adequate precautions to prevent such freezing.

3.4. Mature concrete, when subjected to subfreezing temperatures, develops pressure within the pores of cement paste due to freezing and expansion of water therein. Similar phenomenon may also occur within the aggregates, depending on their porosity and pore sizes. When the pressure surpasses the tensile strength of concrete, the pore walls are ruptured and concrete gets damaged, resulting in surface scaling. Use of de-icing salts for clearing the pavement of snow and ice can further enhance surface scaling. In case of pavements having shrinkage or other surface cracks, such cracks can also gradually propagate further in depth as well as extent under the repeated wedging action of water penetrating therein and freezing. Certain precautions taken initially at the time of construction can help reduce these problems substantially.

4. CONCRETE PAVEMENTS IN FROST AFFECTED AREAS - DESIGN ASPECTS

4.1. Pavement Foundation

4.1.1. In frost affected areas, the sub-base may consist of any of the sepcifications given in section 6.3.1. of IRC: 15-1981 with the additional provison that in case of stabilised semi-rigid materials, their 7 days compressive strength, when cured under wet condition, shall not be less than 35 kg/cm^2.

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4.1.2. For protection against frost action, the balance thickness between frost depth and total pavement thickness including the sub-base should not contain any frost susceptible material. In case the existing subgrade material is forst susceptible, pavement may be protected either by raising the formation level using non-frost susceptible materials or by replacement of frost susceptible materials to required depth by non-frost susceptible ones. For this purpose, for moderate conditions such as those prevailing upto an altitude of 3000 m, the thickness of frost depth may be taken as 45 cm. For extreme conditions, the foundation may be designed individually for each location after determining the frost depth.

4.1.3. The suggested criteria for selection of non-frost susceptible materials are given in Table 1.

TABLE 1

Foundation material	Maximum per cent passing IS: Sieve No.	
	75 micron	50 micron
Graded gravel	8	—
Poorly graded sand	10	5
Fine uniform sand	18	8

In case of graded gravel, the plasticity index and liquid limit should also not exceed 6 and 25 respectively.

4.2. Paving Concrete

4.2.1. To improve the durability of paving concrete against frost action, air-entrained concrete should be used, with air-entrainment of the order of 4 per cent.

4.2.2. Air-entrainment reduces concrete strength to the extent of about 5 per cent for each per cent of air-entrained, and at the same time improves the workability of concrete. However, reduction in strength can be only partly offset by reduction in water content to readjust the increased workability, and the air-entrained concrete mix should be specifically designed for the stipulated strength and workability requirements.

5. PRECAUTIONARY MEASURES AGAINST ADVERSE EFFECTS OF COLD WEATHER CONCRETING—MATERIALS

5.1. Aggregates

5.1.1. Special attention is required for selection of quality aggregates for concrete subject to sub-freezing temperatures. Dense, hard, sound aggregates, with little or no water absorption are desirable, as porous aggregates with high water absorption can crack on freezing of the absorbed moisture therein. Porosity, water absorption and soundness in freeze-and-thaw tests need particular consideration in evaluation of any aggregate for suitability for such concrete.

5.1.2. At the time of use in construction, the aggregate should not contain frost, ice, snow or lumps of hardened mass resulting therefrom.

5.2. Cement

5.2.1. In view of slower rate of strength development at lower temperatures use of Rapid Hardening Portland Cement conforming to IS : 8014-1976 or High Strength Ordinary Portland Cement conforming to IS : 8112-1976 is imperative. In case Ordinary Portland Cement (IS : 269-1976) is used, it is desirable to use an accelerator therewith. Such accelerators may also be used in conjunction with Rapid Hardening Portland Cement and High Strength Ordinary Portland Cement. High Alumina Cement may also be used with certain precautions, at locations where maximum concrete temperature is not likely to rise above 18°C at any time during its service life.

5.3. Admixtures

5.3.1. Admixtures for air-entrainment and/or accelerating the strength development of concrete should conform to the requirements of IS : 9103-1979: "Specification for Admixtures for Concrete".

5.3.2. The dosage of calcium chloride, when used as an accelerator to promote early hardening of concrete, should not exceed 2 per cent by weight of cement. Calcium chloride should be used in the form of solution prepared by dissolving 45 kg of granulated or flaked calcium chloride in 95 litres of water. Not more than 2-3 litres of this solution should be added per 50 kg bag of cement, and this solution should be treated as a part of

the mixing water. Calcium chloride should be used only in case of unreinforced concrete pavements.

6. PRECAUTIONARY MEASURES AGAINST EFFECTS OF COLD WEATHER CONCRETING—PRODUCTION, PLACEMENT AND CURING

6.1. Wherever cold weather conditions are likely to arise during concreting operations, all the needed cold weather concreting measures should be planned well in advance of expected low temperatures. The necessary special equipment and materials must be available at work site before low temperatures occur.

6.2. Production

6.2.1. Concrete at the time of placing between the forms should have a temperature of at least 15°C and not exceeding 32°C. This may be done by preheating the materials—water and aggregates. Estimation of temperature of freshly mixed concrete from the temperatures and proportions of mix ingredients may be made using correlations given in the *Appendix*.

6.2.2. In case concrete is to be heated during mixing, the equipment used should be such as to heat the mass uniformly and should preclude the possibility of overheated zones which might effect the properties of concrete. Heating methods which alter or prevent the entrainment of required amount of air in the concrete should not be adopted.

6.2.3. For air temperature not lower than—1°C, it may be adequate to heat the mixing water alone. Below this temperature, both water and fine aggregate should be heated. When air tempratures fall still lower, coarse aggregate should also be heated. Aggregates should be heated in such a manner that frozen lumps are eliminated and that overheating or excessive drying is avoided. At no point should the aggregate temperature exceed 100°C and the average temperature of an individual batch of aggregate should not exceed 66°C. The mixing water should also not be heated beyond 66°C.

6.2.4. When either aggregate or water is heated to a temperature exceeding 38° C, loading of mixer should be so carried out that cement does not come in contact with the hot materials To ensure this, the heated material may first be fed in to the mixer along with part of the unheated material, and then cement and remaining unheated material may be added.

6.3. **Placement**

6.3.1. The temperature of all surfaces to be in contact with concrete should be raised above the freezing point, and they should be free of all ice, snow, frost, etc. No concrete should be laid on a frozen subgrade or on that which contains frozen material. The pavement foundation and subgrade should be protected against frost prior to concreting. It should also be ensured that it does not freeze when concrete is laid. For this purpose, it may be protected by layers of straw or other insulating materials, or kept warm by means of braziers or other hot air equipment.

6.3.2. Prior heating of concrete transporting equipment to prevent fall in temperature during transportaion may be done to prevent cooling/freezing of concrete during transport to the point of laying. This could be conveniently done by storing the equipment in hot air enclosure or by means of steam jets. Suitable covering should be provided over concrete during transport if distance involved is sizeable.

6.3.3. Transport and placement operations, including compaction and finishing should be done as fast as practicable to reduce fall in temperature of concrete during the operations.

6.3.4. During placement of concrete, tarpaulin covers or other readily removable covering should closely follow the placing of concrete, so that only a few metres of the finished slab are exposed to the outside air at any one time. The coverings may be so arranged that heated air, where provided, may freely circulate on top of the pavement. The coverings, may be further covered by layers of straw or other insulating materials, no sooner the wet concrete is strong enough to take their load.

6.4. **Curing**

For curing of concrete in cold weather, operations, stipulations of IRC: 84-1983 "Code of Practice for Curing of Cement Concrete Pavements" should be followed.

7. QUALITY CONTROL

7.1. Arrangements for covering or protecting newly placed concrete should be adequate to maintain the recommended curing temperatures and moisture conditions in all parts of the concrete. As heated air is likely to be dry, all concrete surfaces should be kept continuously moist.

7.2. In addition to quality control test for materials and

concrete as per IRC: 15-1981 and IRC SP: 11-1977 "Handbook of Quality Control for Construction of Roads and Runways", regular tests, at least twice daily, should be conducted on air content of concrete, as per procedure stipulated in IS: 1199-1959, wherever air-entrained concrete is used.

7.3. Any concrete, frozen or showing signs of frost damage, should be immediately removed and replaced with good quality concrete. Such replacement should extend to a distance of at least 30 cm beyond the area noticed to be frozen in case of concrete, which is still in the plastic stage. In case of hardened concrete, entire affected panels between adjacent expansion/contraction joints should be removed and replaced.

Appendix

ESTIMATION OF TEMPERATURE OF FRESHLY MIXED CONCRETE FROM THE TEMPERATURES AND PROPORTIONS OF THE MIX INGREDIENTS

The temperature of freshly mixed concrete can be estimated from the temperatures and proportions of the mix ingredients, using the formulae given below :

$$t = \frac{W_a\, t_a\, S_a + W_c\, t_c\, S_c + W_w\, t_w\, S_w}{W_a\, S_a + W_c\, S_c + W_w\, S_w} \quad \ldots \quad (1)$$

with t = temperature of freshly mixed concrete (°C)

t_a, t_c, t_w = temperature of aggregate, cement and mixing water respectively (°C)

S_a, S_c, S_w = specific heats of aggregate, cement and water respectively (cal/gm oC)

W_a, W_c, W_w = weight of aggregate, cement, and water respectively (kg)

As S_a, S_c = 0.22, and S_w = 1, the formula reduces to :

$$t = \frac{0.22\,(W_a\, t_a + W_c\, t_c) + W_w\, t_w}{0.22\,(W_a + W_c) + W_w} \quad \ldots \quad (2)$$

Note : In case the aggregates contain some free water, its temperature will be the same as that of the aggregate. Moreover, the water added at the mixer will be adjusted in this case to allow for the free water in the aggregate, such that :

$$W_w = W_{wm} + W_{wa} \quad \ldots \quad (3)$$

with W_{wm} = water added at the mixer (temperature t_w)

W_{wa} = free water present in the aggregate (temperature t_a)

$$t = \frac{0.22\,(W_a\, t_a + W_c\, t_c) + W_{wm}\, t_w + W_{wa}\, t_a}{0.22\,(W_a + W_c) + (W_{wm} + W_{wa})} \quad \ldots \quad (4)$$

30.	O. Muthachen	Poomkavil House, Somangalam, Punalur (Kerala)
31.	P. K. Nagarkar	Chief Engineer & Director, Maharashtra Engineering Research Institute
32.	K. K. Nambiar	Ramanalaya, 11, First Crescent Park Road, Adyar, Madras
33.	T. K. Natarajan	Deputy Director & Head, Soil Mechanics Division, Central Road Research Institute
34.	P. Patnaik	Chairman, Orissa Bridge Construction Corporation
35.	Y. R. Phull	Deputy Director & Head, Roads Division, Central Road Research Institute
36.	Rajinder Singh	Chief Engineer, Jammu P.W.D., B & R
37.	G. Raman	Director (Civil Engg.), Indian Standards Institution
38.	Prof. M. S. V. Rao	Head of the Deptt. of Traffic & Transportation, School of Planning & Architecture
39.	V. S. Rane	Secy. to the Govt. of Maharashtra PW & H Department (Retd.)
40.	A. K. Roy	Director, SURAD, Calcutta Metropolitan Development Authority
41.	Maj. Gen. J. C. Sachdeva	Director General Border Roads
42.	Dr. O. S. Sahgal	Principal, Punjab Engineering College, Chandigarh
43.	Satish Prasad	AI-103, Safdarjung Enclave, New Delhi
44.	A. Sankaran	Chief Engineer (Evaluation) Income Tax Department
45.	Dr. A. C. Sarna	Head, Traffic Division, Central Road Research Institute
46.	N. Sen	Chief Engineer, Ministry of Transport (Retd.)
47.	G. M. Shonthu	Chief Engineer, Kashmir P.W.D., B & R
48.	S. B. P. Sinha	Engineer-in-Chief-cum-Addl. Commissioner-cum-Spl. Secretary, Bihar P.W.D., B & R
49.	J. S. Sodhi	Chief Engineer (South), Punjab P.W.D., B & R
50.	Dr. N. S. Srinivasan	Executive Director, National Transportation Planning and Research Centre
51.	Prof. C. G. Swaminathan	Director, Central Road Research Institute (Retd.)
52.	K. P. Nair	Research Manager, R & D Centre, Indian Oil Corporation Ltd., Faridabad
53.	Ravinder Kumar	Director, U.P. P.W.D. Research Institute
54.	C. D. Thatte	Director, Gujarat Engineering Research Institute
55.	The Director (D. Mohan)	Highways Research Station, Madras
56.	The Director (S.K. Dey Sarkar)	R & B Research Institute, Pailan, West Bengal

57. The President, Indian Roads Congress (K. Tong Pang Ao) -*Ex-officio*
58. The Director General (Road Development) & Addl. Secy. to the Govt. of India (K. K. Sarin) -*Ex-officio*
59. The Secretary, Indian Roads Congress (Ninan Koshi) -*Ex-officio*